Appendix B: Water Quality Data Collection Explanation and Results

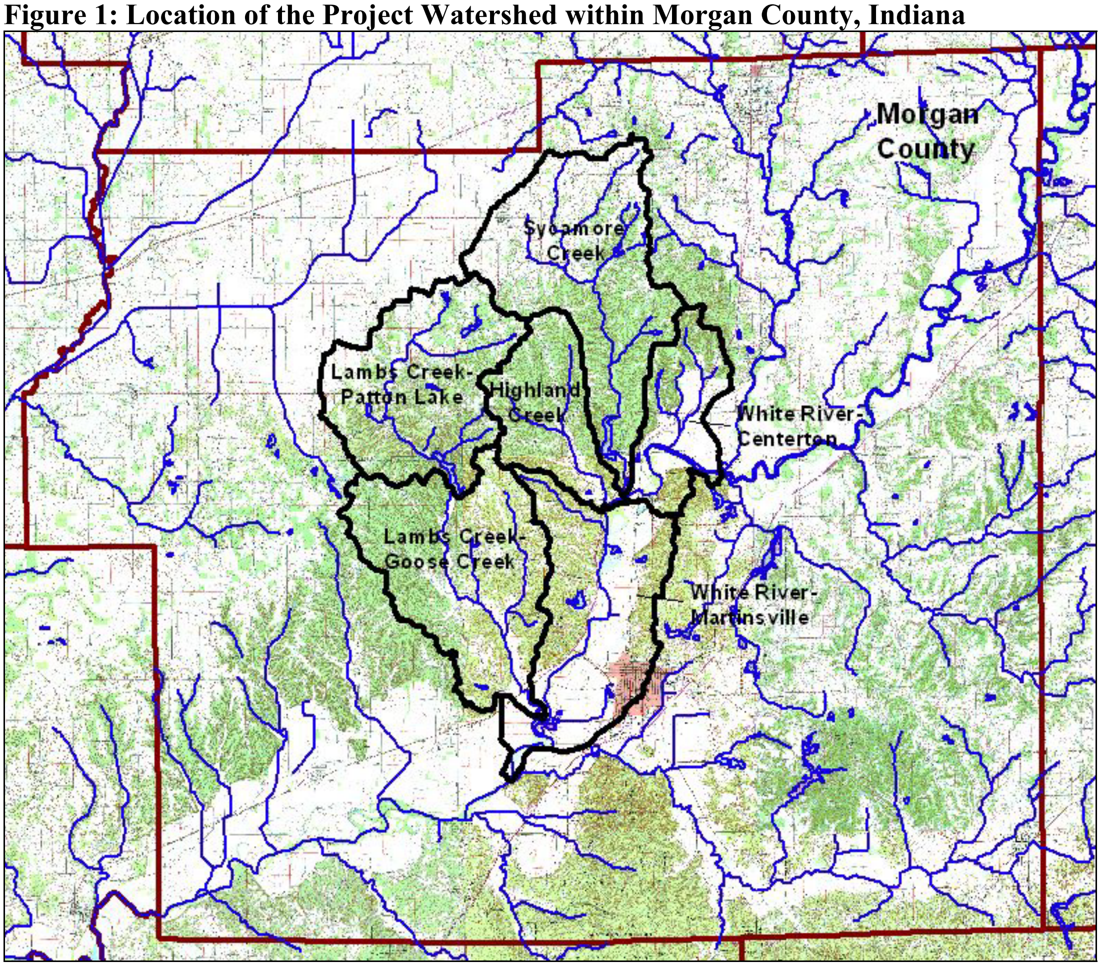
Morgan County Watershed Initiative - Water Quality Assessment Project

Project Description

The West Central Morgan County White River Watershed (HUC 05120201160), a watershed within the larger West Fork White River Basin (HUC 05120201), is located completely within Morgan County, Indiana (**Figure 1**). Drainage from the three major tributaries within this 11-digit HUC watershed (Lambs Creek, Sycamore Creek and Highland Creek) discharges directly into the West Fork of the White River.

Like many waterbodies in the White River Basin, streams within this Morgan County watershed have suffered from the impact of both agriculture and urbanization. Although land uses predominately consist of deciduous forest, future growth and development in and around the Cities of Martinsville, Mooresville and Monrovia, as well as along the SR 67 corridor could potentially increase pollutant loads and storm water runoff volumes in the watershed. Concerns identified in IDEM's 2000 Unified Watershed Assessment regarding the density of septic systems and the 1998 303(d) listings for Lamb's Creek (*E. coli.*) were perceived to be indicative of problems with failing septic systems, agriculture, and wildlife within the watershed. Several of these suspected problems could be exacerbated with increased development pressures.

Figure 1: Location of the Project Watershed within Morgan County, Indiana



In an effort to better identify pollutant problems and to prioritize areas for pollutant reduction or mitigation efforts, the Morgan County Watershed Initiative (MCWI) contracted with Goode & Associates, Inc. to conduct a water quality monitoring program as described in this document. Monitoring results were used to assist in identifying broad, watershed-wide water quality problems and in developing this watershed management plan.

Project Objectives

The goal of the project was to document the physical, biological and chemical conditions of the watershed from which a watershed management plan could be developed. Data collected by the project was used to make broad management decisions on a watershed scale. More specifically, data collected by the study was compared to concentration based water quality standards to identify "hot spots" in the watershed where water quality standards are not being met; to suggest appropriate Best Management Practices (BMPs) to curb current ecological degradation in the watershed; and to guide future development in the watershed while maintaining its ecological health. The data collected during this study will also serve as baseline data to track changes in conditions of the watershed. Additionally, the data may be used as baseline data to track the success of any restoration efforts undertaken as a result of the management plan.

Project goals were accomplished by:

- Documenting the physical conditions of the watershed such as land use, soils, and stream habitat.
- Collecting and analyzing water quality and biological data.
- Developing a watershed management plan that addresses any water quality impairments identified via project monitoring.

To achieve the goal of evaluating and ranking "hot spots" in the watershed relative to one another and thus assisting the prioritization of management efforts, emphasis was placed on maintaining standard procedures at each water quality sampling station. Consistencies in protocol ensured sampling stations could be compared to one another, enabling the Project Manager to determine which sites were most degraded relative to others in the watershed.

Project Monitoring Sites

Water chemistry monitoring sites were selected to achieve a representation of each major tributary within the watershed; however, sites were not located within sub-watersheds that were primarily representative of the main stem of the White River. It was determined that the IDEM Water Assessment Branch maintains a fixed monitoring station on the White River within the watershed that is monitored on a monthly basis. In addition, samples collected from IDEM's Fixed Station Program are analyzed by the same laboratory that was used for this project (Indiana State Department of Health Laboratory). As a result, the main stem of the White River is adequately monitored and the data is of a public nature such that the information should be available, comparable, and usable for this project.

Preliminary selection for chemical monitoring sites was based on map analysis. This analysis consisted of locating major tributaries that also have access points (road crossings). This approach attempts to establish sampling stations in various subwatersheds to determine which streams are contributing the most pollutants. The sampling stations that were selected based on map analysis were then field checked by the Project Manager for verification of site accessibility. Following the field inspection, 9 sampling stations were selected.

Sampling stations were presented to the technical sub-committee of the MCWI's steering committee. Input from the sub-committee and Project Manager narrowed the potential locations to seven sites. The locations of these sites are shown in **Figure 2**. Narrative descriptions of these sites are included in **Table 1**. Landowners at these sampling stations were contacted to obtain permission to conduct sampling in those areas.

Figure 2: Chemical Monitoring Sites

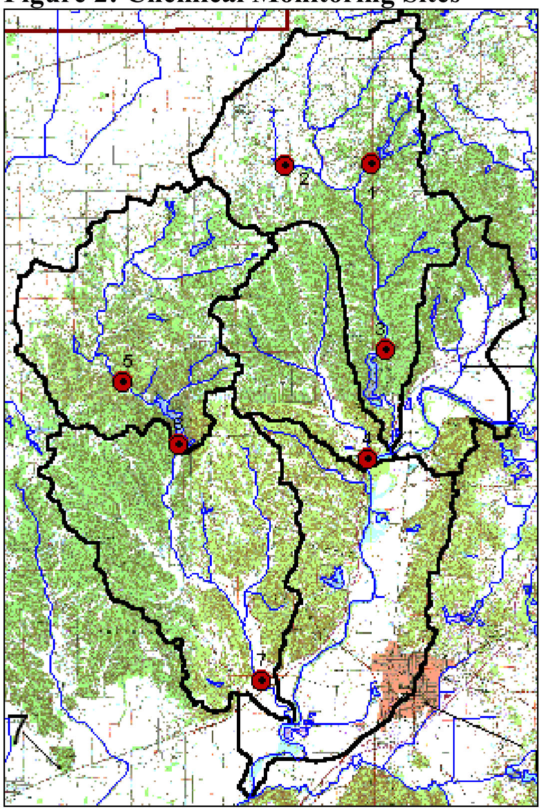


Table 1: Narrative Description of Chemical Monitoring Sites

Site #:	Waterbody Name	Location
Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North
Site 2	Sycamore Creek	CR 950 North
Site 3	Sycamore Creek	Robb Hill Road
Site 4	Highland Creek	SR 67
Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road
Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road
Site 7	Lambs Creek	SR 67

Water quality parameters sampled include pH, temperature, dissolved oxygen, turbidity, specific conductance, *E. coli*, total kjeldahl nitrogen (TKN), total phosphorous, and total organic carbon (TOC). PH, temperature, and dissolved oxygen were analyzed in the field with field equipment. Indiana State Board of Health Laboratory in Indianapolis, Indiana analyzed the remaining parameters at their laboratory.

Sampling Design

Chemical monitoring was conducted on a monthly basis throughout the course of the study. This timing allowed the data to be consistent and comparable with the IDEM's fixed station data being collected within the watershed. Collection of water quality data under this design provided an overview of water quality in the watershed under varying conditions and was sufficient for accomplishing the goals of the water quality monitoring program outlined in the project objectives. The water quality sampling schedule was flexible to prevent sampling during inappropriate weather or when equipment was not working.

Although the MCWI contracted with Goode & Associates to conduct water quality monitoring on a monthly basis from January 2002 through March 2003, the timeline for development of the watershed plan required that an evaluation of the data occur prior to full completion of the monitoring contract. Consequently, all observations discussed in this report reflect one year of water quality monitoring data collected from January 2002 through January 2003 (Samples were not collected in June 2002 due to logistical problems).

Goode & Associates collected water quality samples from the sampling sites in the Morgan County watershed on a monthly basis during the study period. Samples were typically collected on the last Wednesday of every month, where feasible, however, this schedule was altered on several occasions to accommodate logistical problems. These monitoring dates are listed in **Table 2**.

Table 2: Chemical Monitoring Dates/ Streamflow Conditions

Monitoring Date	Streamflow Condition
January 23, 2002	Dry
February 27, 2002	Wet
March 27, 2002	Wet
April 30, 2002	Wet
May 30, 2002	Wet
July 31, 2002	Dry
August 28, 2002	Dry
September 30, 2002	Wet
October 30, 2002	Wet
November 26, 2002	Dry
December 30, 2002	Dry
January 31, 2003	Dry

As a result of the consistent monthly monitoring regime, chemical monitoring data collected for this project is considered to be representative of the variety of stream flow conditions experienced in the watershed during the study period, including both dry and wet weather events. Stream flow conditions during any given sampling event are determined by comparing the measured stream flow at a nearby USGS stream discharge monitoring station to the median daily streamflow for the period of record. The following two USGS gauging stations were used to evaluate streamflow conditions:

- USGS 03353800 – White Lick Creek at Mooresville, Indiana
- USGS 03354000 – White River near Centerton, Indiana

Graphs illustrating the daily mean (average) discharges for these USGS gauging stations during the project period are depicted in **Figures 3 and 4**.

The sampling crew collected water at each site in sterile, pre-preserved sample containers, where applicable, supplied by the Morgan County Health Department. Samples were delivered to the Indiana State Department of Health (ISDH) where laboratory analysis was conducted in accordance with the Quality Assurance Project Plan (QAPP) developed for this project (ARN: A305-1-00-216). The QAPP is available on file at the Indiana Department of Environmental Management.

Figure 3: Mean daily discharge for White Lick Creek at Mooresville, Indiana (January 2002 – March 2003)

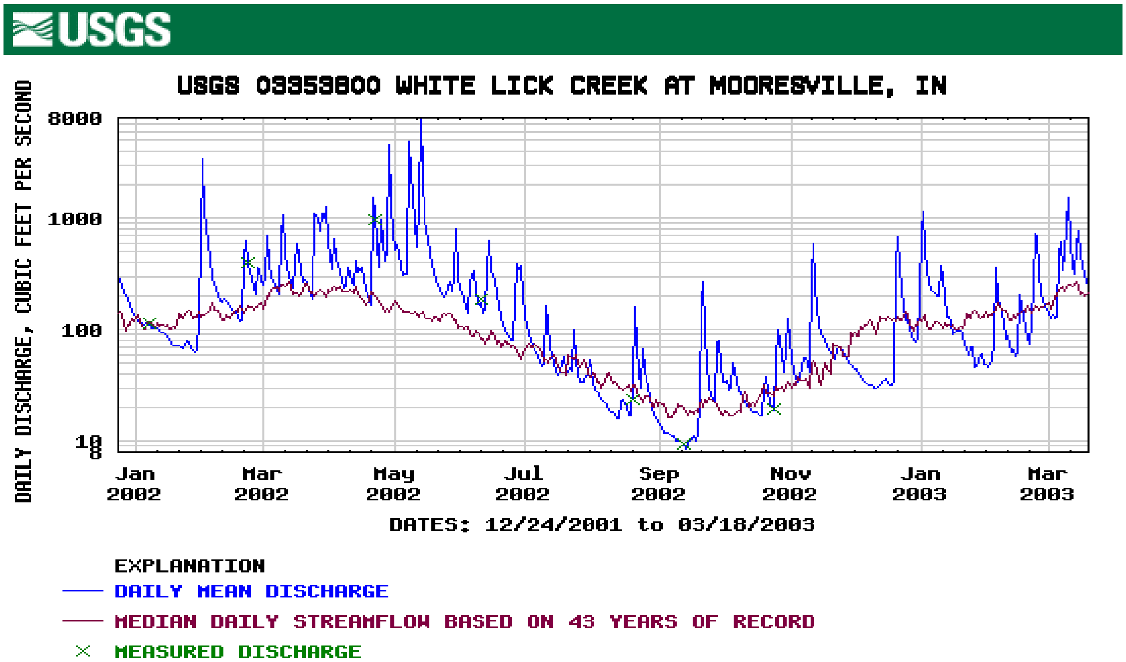
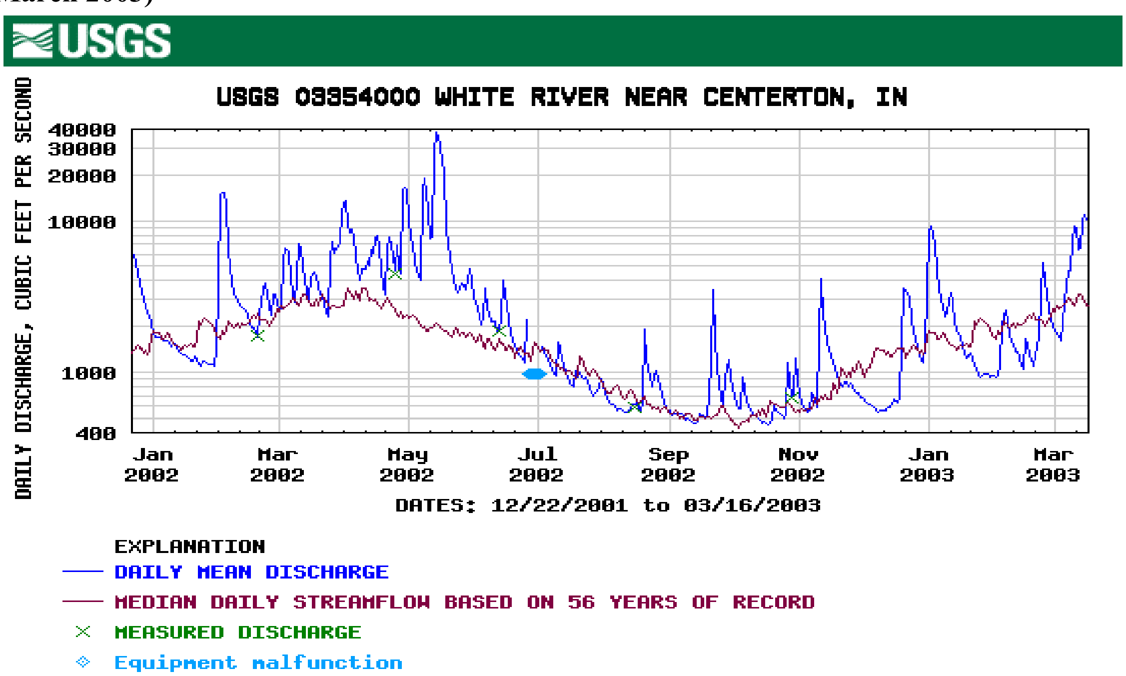


Figure 3: Mean daily discharge for White River near Centerton, Indiana (January 2002 – March 2003)



Water Quality Monitoring Results

Introduction

In most cases, water quality monitoring projects are initiated to document the present condition of a given lake, river, or stream with the expressed intent of understanding how those conditions are positively or negatively affecting the designated uses of the waterbody, i.e. swimming, fishing, or boating. Once an understanding of the waterbody's condition is realized, monitoring results can then be interpreted to help water resource managers better understand the causes and sources of these conditions so that they can make decisions regarding the proper management of the waterbody. By either maintaining, implementing, or mitigating land use practices that are having an impact on water quality, water resource managers have the ability to modify the factors contributing to the conditions of the waterbody.

Although very limited in size, scope and budget, the water quality monitoring completed for this project provides some insights regarding the existing conditions of several small watersheds in the west central portion of Morgan County, Indiana. The purposes of this report is to discuss the water quality monitoring results collected for this project, and when appropriate, discuss the causes and sources of the conditions of the streams within these watersheds.

Evaluating Water Quality Pollutants

A number of substances including bacteria, nutrients, oxygen demanding wastes, metals, and toxic substances, cause water pollution. Causes of pollution refer to the substances that enter surface waters that result in water quality degradation and impairment. Sources of these pollution causing substances are divided into two broad categories: point sources and nonpoint sources (IDEM, 2002). Point and nonpoint sources of pollution are described as follows:

Point sources of pollution refer to discharges that enter surface waters through a pipe, ditch or other well defined point of discharge. The term applies to wastewater and storm water discharges from a variety of sources. Wastewater point source discharges include municipal (city, town, and county) and industrial wastewater treatment plants and small domestic wastewater treatment systems that may serve schools, commercial offices, residential subdivisions and individual homes. Storm water point source discharges include storm water discharges associated with industrial activities and storm water discharges from municipal separate storm sewer (MS4s) systems for municipalities that meet the requirements of 327 IAC 15-13.

The primary pollutants associated with point source discharges are bacteria, oxygen demanding wastes, nutrients, sediment, color and toxic substances including chlorine, ammonia and metals. Point source dischargers in Indiana must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the state. Discharge permits are issued under the NPDES program (See Appendix A), which is delegated to Indiana by the US Environmental Protection Agency (EPA).

Nonpoint sources of pollution refer to discharges of runoff that enter surface waters from storm water runoff, contaminated ground water, snowmelt or atmospheric deposition. There are many types of land use activities that can serve as sources of nonpoint source pollution including land development, construction, mining operations, crop production, animal feeding lots, timber harvesting, failing septic systems, landfills, roads and paved areas, and wildlife.

Sediment and nutrients are major pollution causing substances associated with nonpoint source pollution. Others pollutants can include *E. coli* bacteria, heavy metals, pesticides, oil and grease, and any other substance that may be washed off the ground or removed from the atmosphere and carried into surface waters. Unlike point source pollution, nonpoint pollution sources are diffuse in nature and occur at random depending on rainfall events.

Types of Pollution

Causes of pollution refer to the substances that enter surface waters from point and nonpoint sources and result in water quality degradation and impairment. Major causes of water quality impairment include *E. coli* bacteria, biochemical oxygen demand (BOD), nutrients, and toxicants (such as polychlorinated biphenyls [PCBs] and ammonia). The following discussion provides a general overview of causes of impairment and the activities that may lead to their introduction into surface waters (IDEM, 2002).

Bacteria

E.coli bacteria are associated with the intestinal tract of warm-blooded animals. Although not a pollutant in itself, *E.coli* is widely used as an indicator of sewage pollution, which may harbor additional waterborne disease causing (pathogenic) bacteria, protozoa, and viruses. *E.coli* is also used as an indicator because it is easier and less costly to monitor and detect than the actual pathogenic organisms, such as *Giardia*, *Cryptosporidium*, and *Shigella*, which require special sampling protocols and very sophisticated laboratory techniques. The presence of these waterborne disease-causing organisms can cause outbreaks of diseases, such as typhoid fever, dysentery, cholera, and cryptosporidiosis.

Water quality standards (WQS) for *E.coli* bacteria have been established in order to ensure safe use of waters for drinking water and recreation. 327 IAC 2-1-6 Section 6(d) states that *E.coli* bacteria, using membrane filter count (MF), shall not exceed 125 per 100 milliliters as a geometric mean based on not less than five samples equally spaced over a 30 day period nor exceed 235 per 100 milliliters in any one sample in a 30 day period.

E.coli bacteria may enter surface waters from nonpoint source runoff from failing septic systems, straight pipe discharges from septic tanks, livestock, domestic pets, and wildlife. In addition, *E.coli* can also come from improperly treated discharges of domestic wastewater. Common sources of *E.coli* bacteria include leaking or failing septic systems, direct septic discharge, leaking sewer lines or pump station overflows, runoff from livestock operations, urban storm water and wildlife. *E.coli* bacteria in treatment plant effluent are controlled through disinfection methods including chlorination, ozonation or ultraviolet light radiation.

E.coli monitoring by the IDEM in the Lambs Creek watershed identified several locations where the WQS for *E.coli* was violated during 1996. Lamb's Creek is listed as impaired by *E.coli* on the 2002 Indiana 303(d) list. These stream segments are scheduled for TMDL development from 2003-2005.

In addition to the IDEM's monitoring data, water quality monitoring conducted for this project confirmed the presence of ongoing *E.coli* violations at several locations on Lamb's Creek. Violations of the *E.coli* water quality standard were also detected at monitoring sites on Sycamore Creek and Highland Creek (see **Graph 1**).

Monitoring locations were prioritized according to the level of impairment, which was judged by the percentage of execeedances of the *E.coli* water quality standard at each site (**Table 3**). In most cases, the percentage method of prioritizing sites is appropriate for identifying stream segments with the most need for mitigation; however, this ranking is independent of the results from other parameters.

Graph 1: *E.coli* Sampling Results, 2002 - 2003

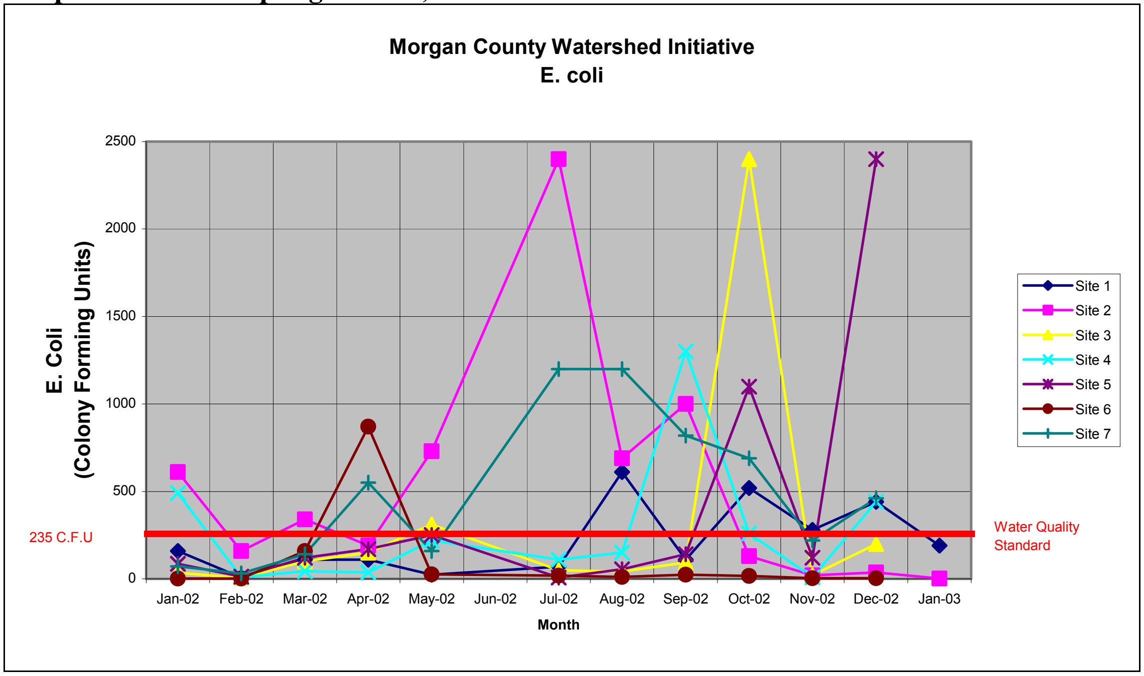


Table 3. E.coli Monitoring Results (Average and Median) in Colony Forming Units (CFUs); Percentage of Samples Exceeding Water Quality Standards (WQS) of 235 CFU; Priority Ranking of Sites (1 = Least Impaired, 6 = Most Impaired)

Site #	Average CFU	Median CFU	% of Samples Exceeding WQS	*Priority Ranking
Site # 1	219.08	135	33%	**3**
Site # 2	525.67	265	50%	**5**
Site # 3	309.55	93	18%	**2**
Site # 4	279.27	150	33%	**4**
Site # 5	405.45	120	27%	**3**
Site # 6	95.33	14.5	9%	**1**
Site # 7	504	460	55%	**6**

Site 2 (Sycamore Creek downstream of Monrovia) and Site 7 (Lower Lamb's Creek) would be considered the most impacted sites for *E.coli* within the project area. Site 1 (Sycamore Creek below Hart Lake), Site 4 (Highland Creek) and Site 5 (Lamb's Creek upstream of Patton Lake) also experienced frequent periods of impairment from *E.coli*. Site 3 (Sycamore Creek) and Site 6 (Lamb's Creek downstream of Patton Lake) had minor problems with *E.coli*.

The sources of E.coli at Site 2 likely originate from the Town of Monrovia from either domestic wildlife, failing septic systems, or inadequate wastewater treatment at Monrovia Middle School or the municipal wastewater treatment plant. Monitoring conducted for this project was not of sufficient detail to distinguish between these potential sources.

The sources of E.coli at Site 7 likely originate from cattle livestock operations immediately upstream of the monitoring site and/or failing septic systems as far upstream as Patton Lake.

The sources of E.coli at Site 1 are most likely associated with native wildlife and/or failing septic systems.

The sources of *E.coli* present Site 4 and Site 5 were not readily apparent; however, both sites had stream habitat conditions that were observed to be somewhat degraded or stagnant due to the presence of several beaver dams within the monitored stream reach, possibly suggesting wildlife contributions of *E.coli*. Land use observations indicate that the drainage area upstream of Site 4 consists of small bottomland farms practicing row crop agriculture within the subwatershed that could support small quantities of livestock and/or failing septic systems that may also be contributing to the *E.coli* violations observed at this site.

Oxygen Consuming Wastes

Since maintaining sufficient levels of dissolved oxygen in a waterbody is critical to the survival of most forms of aquatic life, evaluating oxygen-consuming wastes in a river or stream is central to diagnosing the health of a river system or watershed. Pollutants associated with oxygen consuming wastes are typically composed of either decomposing organic matter or chemicals that bind with available instream oxygen to reduce the available concentrations of dissolved oxygen in the water column. Organic causes of oxygen consuming wastes are measured as biochemical oxygen demand (BOD) and chemical causes of oxygen consuming wastes are measured as chemical oxygen demand (COD); however, the concentration of dissolved oxygen in a waterbody is used as a common indicator of the general health of an aquatic ecosystem.

327 IAC Section 6 (b)(3) states that concentrations of dissolved oxygen shall average at least five milligrams per liter per calendar day and shall not be less than four milligrams per liter at any time. Dissolved oxygen concentrations are affected by a number of factors. Physical conditions, such as lower water temperatures generally allow for retention of higher dissolved oxygen (DO) concentrations. In addition, higher dissolved oxygen concentrations can be naturally or artificially produced by turbulent actions, such as by instream riffles or by the cascading effect of a waterbody spilling over a dam, which inject air into surface waters. Low dissolved oxygen levels tend to occur more often in warmer, slow moving waters. In general, the lowest dissolved oxygen concentrations occur during the warmest summer months and particularly during periods of low stream flow.

Violations of the water quality standard for dissolved oxygen were detected at monitoring sites on Highland Creek and Lamb's Creek (see **Graph 2**).

As illustrated in **Table 4**, monitoring locations were prioritized according to the level of impairment, which was judged by the percentage of execeedances of the dissolved oxygen water quality standard at each site. For sites without violations, rankings are based on which sites maintained the highest average dissolved oxygen results. Note: This ranking is independent of the results from other parameters.

Monitoring results indicate that Site 4 (Highland Creek) and Site #6 (Lambs Creek downstream of Patton Lake) experienced the lowest dissolved oxygen levels of the seven sampling locations.

Graph 2: Dissolved Oxygen (DO) Results, 2002 – 2003

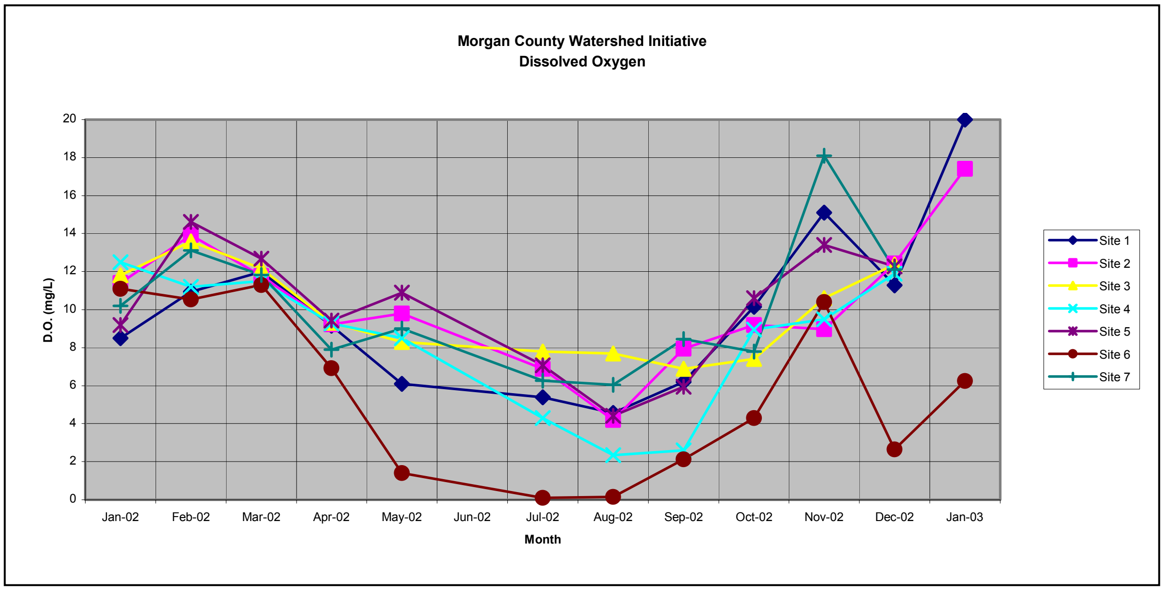


Table 4. Dissolved Oxygen Monitoring Results (Average and Median) in Milligrams per Liter (Mg/L); Percentage of Samples Exceeding Water Quality Standards (WQS) of 4 Mg/L; Priority Ranking of Sites (1 = Least Impaired, 6 = Most Impaired)

Site #	Average Mg/L	Median Mg/L	% of Samples Exceeding WQS	*Priority Ranking
Site # 1	10.0	9.7	0%	**3**
Site # 2	10.6	9.5	0%	**1**
Site # 3	9.8	9.3	0%	**4**
Site # 4	8.4	9.3	18%	**5**
Site # 5	10.1	10.6	0%	**2**
Site # 6	5.7	5.3	42%	**6**
Site # 7	10.1	9.0	0%	**2**

The causes of low dissolved oxygen at Site 4 were likely due to the degraded stream habitat conditions and stagnant water from the presence of several beaver dams within the monitored stream reach. Failing septic systems within the subwatershed may also be contributing organic waste to the stream that can bind oxygen as it decays.

An additional cause of low dissolved oxygen concentrations during the warmer months of the year may be diurnal fluctuations of oxygen in the water column due to conditions of nutrient enrichment. Monitoring detected the presence of elevated concentrations of nutrients (phosphorus and TKN) in sufficient quantities to support an overabundance of algae growth within the stream. Although the process of photosynthesis in the algae produces a large volume of oxygen during periods of daylight, respiration by algae during the nighttime hours absorbs more oxygen than the water column can maintain, resulting in times when dissolved oxygen concentrations are significantly reduced or depleted. This situation can be intensified in hot weather and low flow conditions due to the reduced capacity of water to retain dissolved oxygen.

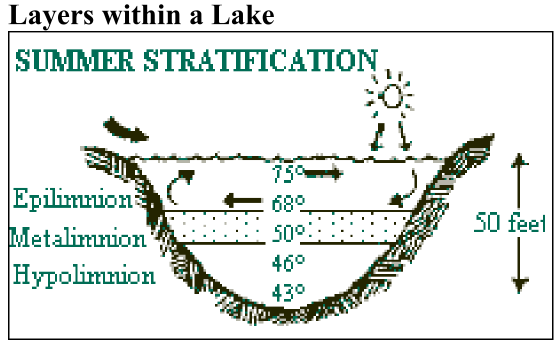
The cause of low dissolved oxygen at Site 6 is due to the anoxic (lacking oxygen) condition of the discharge from the bottom of Patton Lake. Water quality in a lake can be affected by how much of the water mixes. Lake depth, size, and shape all are factors that influence mixing and the stratification process. Since water density peaks at 39 Degrees Fahrenheit, water at that temperature is the heaviest and will move to the bottom of the lake. Any water above or below this temperature will be lighter and move up in the water column. Density variations due to temperature differences can prevent warm and cold water from mixing.

In early spring when ice melts, the temperature and density of the water in the lake will be relatively the same from top to bottom. This allows all of the water to mix together, where the cold water from the bottom will move towards the surface, and the warmer surface water is mixed downward. Nutrients that were in the bottom sediments are brought up in the water column, and the cold water is replenished with oxygen. In the process the water becomes uniform in nearly all respects, including temperature, density, dissolved oxygen content, and nutrients. This phenomenon is referred to as the spring overturn. Later in the spring, the water nearest the surface warms and loses density. This leads to distinct temperature layers in the lake. This layering effect is called stratification. The cooler temperature of the discharge from Patton Lake at Site 6 is illustrated in **Graph 3**.

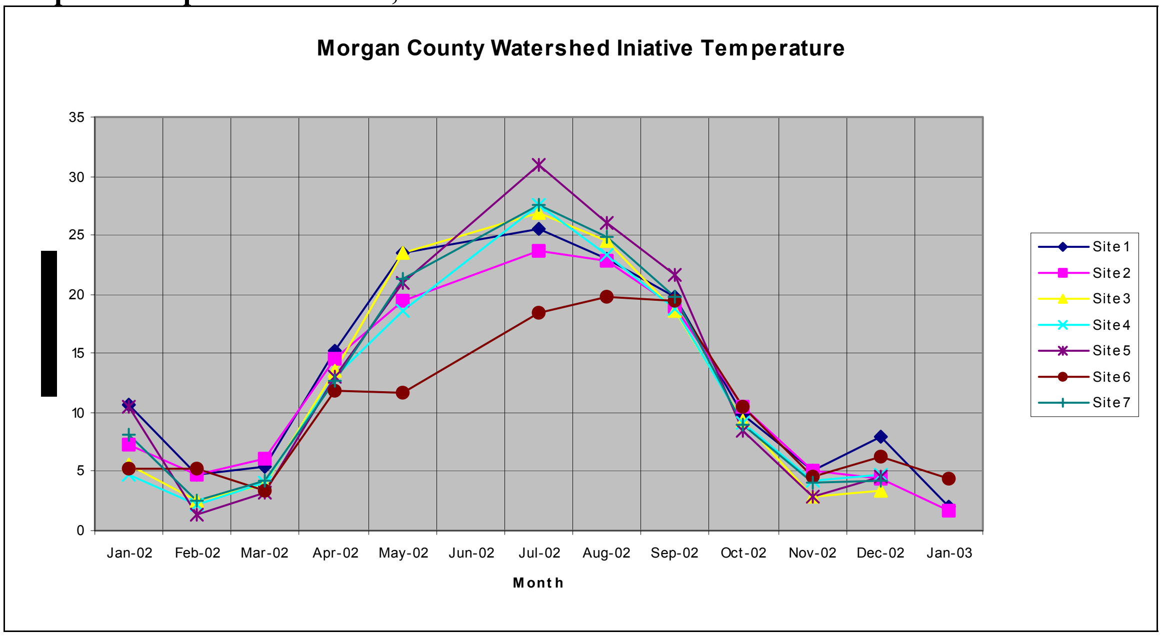
There are three layers in a stratified lake: the epilimnion, metalimnion, and hypolimnion (see **Figure 4**). The epilimnion is the layer nearest the surface, and also the warmest layer. The middle layer is called the metalimnion. The metalimnion contains the thermocline, which is the depth at which the water stops mixing, and a sharp temperature decline results. The metalimnion is the transition zone between the warm surface waters that mix, and the unmixed cold water of the bottom layer, or hypolimnion.

In stratification, the hypolimnion traps nutrients released from bottom sediments from being mixed throughout the lake. Eventually, as the lake has been stratified for long enough, all of the oxygen in the hypolimnion gets used up in respiration by small organisms, plants, or fish. This condition is called anoxia (oxygen depletion). Eutrophic lakes are particularly susceptible to oxygen depletion (anoxia) in the hypolimnion.

Figure 4: Example of Stratification Layers within a Lake



Graph 3: Temperature Results, 2002 – 2003



Toxic Substances

327 IAC 2-1-9(45) identifies toxic substances as substances that are or may become harmful to plant or animal life, or to food chains when present in sufficient concentrations or combinations. Toxic substances include those pollutants identified as toxic under Section 307 (a)(1) of the Clean Water Act. Indiana's standards for individual toxic substances are listed in 327 IAC 2-1-6. Toxic substances frequently encountered include chlorine, ammonia, organic pollutants, heavy metals, and pH. These substances can be toxic to aquatic organisms and their effects may be evident immediately or may only be manifested after long-term exposure or accumulation in living tissue (IDEM, 2002).

Whole effluent toxicity testing is required for major NPDES dischargers (discharge over 1 million gallons per day or population greater than 10,000). This test shows if the effluent from a treatment plant is toxic, but it does not identify the specific cause of toxicity. If the effluent is found to be toxic, further testing is done to determine the specific cause. Other testing, or monitoring, done to detect a toxicity problem includes fish tissue analyses, chemical water quality sampling, and biological monitoring.

Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) were first created in 1881 and subsequently began to be commercially manufactured around 1929 (Bunce, 1994). Because of their fire-resistant and insulating properties, PCBs were widely used in transformers, capacitors, and in hydraulic and heat transfer systems. In addition, PCBs were used in products such as plasticizers, rubber, ink, and wax. In 1966, PCBs were first detected in wildlife, and were soon found to be ubiquitous in the environment (Bunce, 1994). PCBs entered the environment through unregulated disposal of products such as waste oils, transformers, capacitors, sealants, paints, and carbonless copy paper. In 1977, production of PCBs in North America was halted. Subsequently, PCB contamination present in our surface waters and environment today is the result of historical waste disposal practices (IDEM, 2002).

Although there are no waterbodies within the project watershed specifically listed for PCB contamination, there is a statewide fish consumption advisory for carp greater than 15 inches in length.

Nutrients

The term "nutrients" primarily refers to the two major plant macronutrients, phosphorus and nitrogen. These nutrients are common components of fertilizers, animal and human wastes, vegetation, and some industrial processes. Nutrients in surface waters come from both point and nonpoint sources. Nutrients are beneficial to aquatic life in small amounts. However, in over abundance and under certain conditions, they can stimulate the occurrence of algal blooms and excessive plant growth in quiet waters or low flow conditions. Algae blooms and excessive plant growth often reduce the dissolved oxygen content of surface waters through plant respiration and the decomposition of dead algae and other plants (IDEM, 2002).

Phosphorus

Nonpoint source discharges are the major sources of phosphorus in most watersheds. Phosphorus can be present as organic matter (living or dead organisms and excreted organic material) and can be either dissolved or suspended in the water column. Phosphorus may also occur in inorganic compounds released from various minerals, fertilizers or detergents that may also be either dissolved or suspended in the water column. Phosphorus is the primary nutrient associated with production of algae and macrophytes (rooted aquatic plants) in waterbodies, as it is generally the nutrient in shortest supply in aquatic systems (Phillips et al, 2000).

Elevated phosphorus concentrations are a cause of pollution in the project watershed. In the absence of a specific surface water quality standard for phosphorus, results from 2002 monitoring project were compared to the results of a statistically based study of the West Fork White River Basin study completed by the IDEM in 1998. The "*1996 Probabilistic Monitoring Program Assessment of the West Fork White River and the Patoka River Basins*" was a probabilistic monitoring study that consisted of a one-time sampling of 27 randomly chosen sites within the West Fork White River watershed designed to gain an understanding of ambient water quality during low flow conditions in the basin. The data from this study were statistically evaluated to create a classification metric based on quartile ranges (IDEM, 1998). The classifications were high, upper ambient, ambient, lower ambient, and low and summary statistics were developed appropriate for establishing metrics for each eight digit HUC watershed within the basin, as well as for the compiled dataset from all seven eight digit HUC watersheds.

In order to best evaluate the phosphorus data collected during this monitoring project, 2002 monitoring results were compared to the summary statistics and classification metrics from the IDEM's 1996 study. An evaluation of the 1996 study's summary statistics indicated that the average concentration of phosphorus for samples collected in the West Fork White River watershed was 0.23 mg/L, while the median concentration of phosphorus was 0.14 mg/L. Concentrations of phosphorus exceeding 0.20 mg/L were considered to be significantly elevated, while concentrations of phosphorus exceeding 0.26 mg/L were considered to be "high".

A comparison of project monitoring results to the mean and median values observed in 1996 reveals that two stream reaches, Site 1 (Sycamore Creek downstream of Hart Lake) and Site 6 (Lamb's Creek downstream of Patton Lake), had monitoring results that exceeded the "high" classification metric from the IDEM's 1996 study (see **Graph 4**).

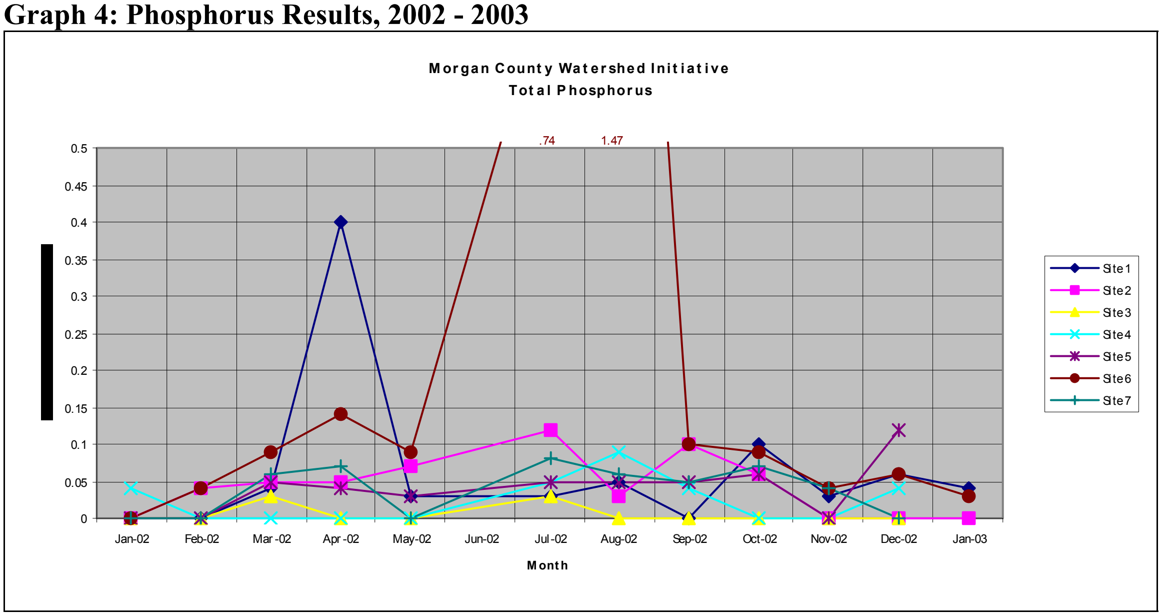
The sources of phosphorus at both Site 1 and Site 6 seem to be tied to the presence of man-made lakes or impoundments in each of the subwatersheds. Phosphorus is mainly introduced to lakes through human activities. Farmland runoff, lawn fertilizers, soil erosion due to construction, sewage from failing septic systems, animal waste, and detergents all account for excess phosphorus entering a lake system. Once phosphorus enters a lake, it may take a long time until it moves out of the lake system. Phosphorus migration depends on the retention time of the lake. Usually after a heavy rainfall, a eutrophic lake will exhibit an algae bloom due to increased phosphorus amount in the lake due to the above reasons.

Phosphorus is by far the most important nutrient in most lakes. Elevated concentrations of phosphorus can promote excessive aquatic plant growth. Phosphorus is rapidly recycled and changes from dissolved to particulate form easily as illustrated in **Figure 5**. Dissolved phosphorus can be used by phytoplankton (floating algae) and macrophytes to grow. Also, once living organisms within a lake die (plants and animals), they sink to the bottom and their phosphorus again becomes unavailable.

In deep stratified lakes there is a limited replenishment of phosphate in surface waters and the quantity of "available" phosphorus in late winter may determine the level of phytoplankton growth that can develop in the summer. Intensive algal growth in spring usually depletes phosphate to levels in the surface waters. Hence, phytoplankton growth during the summer usually occurs shortly after inputs of phosphorus from storm water runoff. Direct sediment resupply is also important during the summer.

Rooted aquatic plants often obtain large quantities of phosphorus from the sediments and can release large amounts into the water. When phosphate levels are low in surface waters, phytoplankton excrete extracellular enzymes called *alkaline phosphatases*, which have the ability to free phosphate bound to organic molecules. Since phosphate is readily adsorbed by soil particles and does not move easily with groundwater, high inflows of total phosphorus are typically due to re-suspension of phosphorus bearing sediments during spring and winter turnovers.

Graph 4: Phosphorus Results, 2002 - 2003

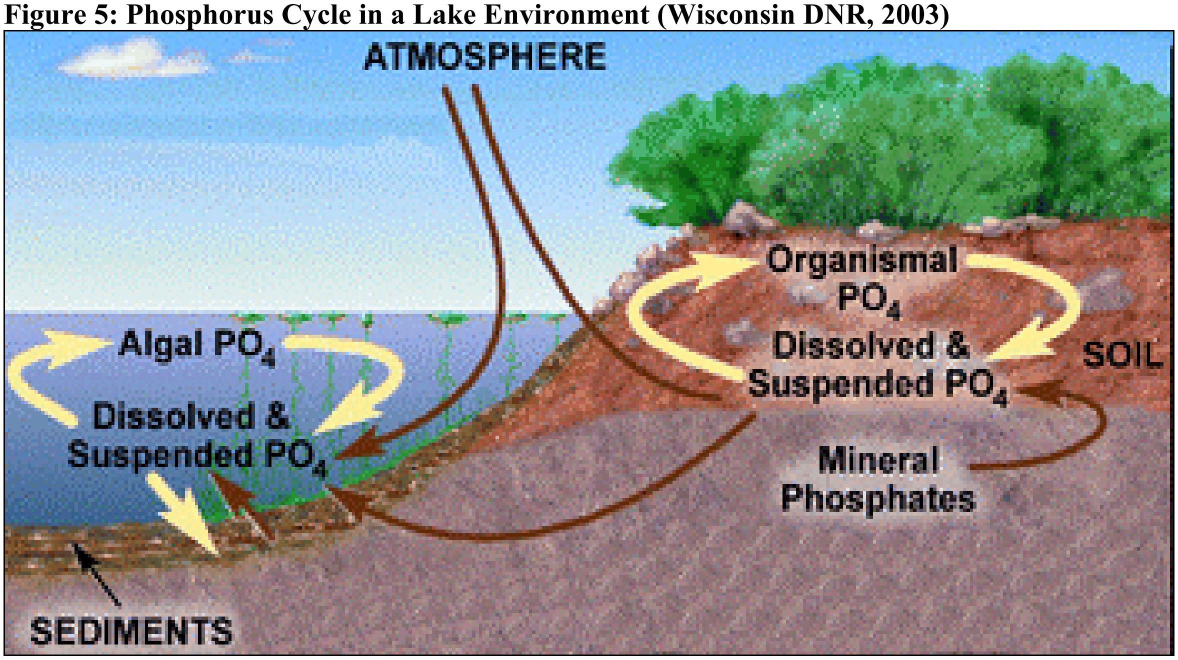


As illustrated in **Table 5**, monitoring locations were prioritized according to the level of phosphorus impairment, which was judged by the percentage of execeedances of the "High" classification metric as compared to the IDEM's 1996 study of the West Fork White River. For sites without exceedances of the high classification, rankings are based on which sites maintained the average phosphorus results. Note: This ranking is independent of the results from other parameters.

Table 5. Phosphorus Monitoring Results (Average and Median) in Milligrams per Liter (Mg/L); Percentage of Samples Exceeding the IDEM's 1996 "High" Classification Metric; Priority Ranking of Sites (1 = Least Impaired, 6 = Most Impaired)

Site #	Average Mg/L	Median Mg/L	% of Samples Exceeding "High"	*Priority Ranking
Site # 1	0.07	0.04	8%	**5**
Site # 2	0.06	0.05	0%	**4**
Site # 3	0.03	0.03	0%	**1**
Site # 4	0.04	0.03	0%	**2**
Site # 5	0.05	0.05	0%	**3**
Site # 6	0.24	0.09	17%	**6**
Site # 7	0.05	0.05	0%	**3**

Figure 5: Phosphorus Cycle in a Lake Environment (Wisconsin DNR, 2003)



Nitrogen (Total Kjeldahl Nitrogen – TKN)
Point source dischargers, such as wastewater treatment plants, can be a significant source of nitrogen in surface waters; however, nonpoint source discharges of untreated septic effluent, decaying organisms, and bacterial decomposition of animal waste from improper disposal or storm water runoff can also contribute to the concentrations of nitrogen in a waterbody.

Elevated TKN concentrations are a cause of pollution in the project watershed. In the absence of a specific surface water quality standard for TKN, monitoring results collected during this project were also compared to the summary statistics and classification metrics from the IDEM's 1996 West Fork White River study. An evaluation of the 1996 study's summary statistics indicated that the average concentration of TKN for samples collected in the West Fork White River watershed was 0.85 mg/L, while the median concentration of TKN was 0.74 mg/L. Concentrations of TKN exceeding 0.91 mg/L were considered to be significantly elevated, while concentrations of TKN exceeding 1.2 mg/L were considered to be "high".

A comparison of project monitoring results to the mean and median values observed in 1996 reveals that three stream reaches, Site 2 (Sycamore Creek downstream of Monrovia), Site 6 (Lamb's Creek downstream of Patton Lake) and Site (Lower Lamb's Creek), had monitoring results that exceeded the "high" classification metric from the IDEM's 1996 study (see **Graph 5**).

As illustrated in **Table 6**, monitoring locations were prioritized according to the level of TKN impairment, which was judged by the percentage of execeedances of the "High" classification metric as compared to the IDEM's 1996 study of the West Fork White River. For sites without exceedances of the high classification, rankings are based on which sites maintained the lowest average TKN results. Note: This ranking is independent of the results from other parameters.

Graph 5: Total Kjeldahl Nitrogen (TKN) Monitoring Results, 2002 - 2003

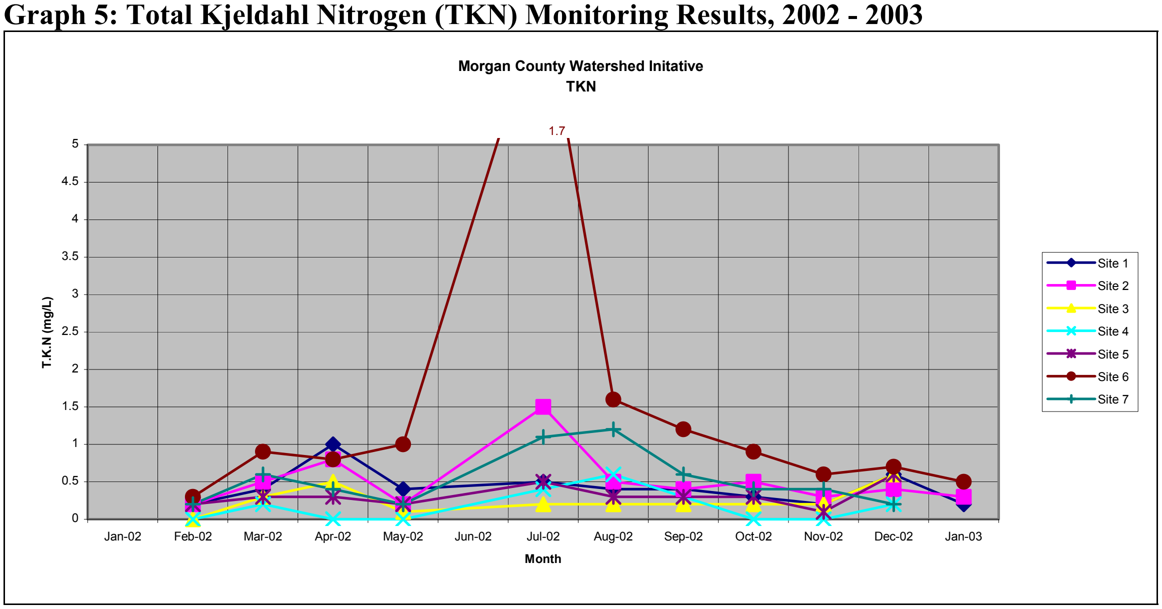


Table 6. TKN Monitoring Results (Average and Median) in Milligrams per Liter (Mg/L); Percentage of Samples Exceeding the IDEM's 1996 "High" Classification Metric; Priority Ranking of Sites (1 = Least Impaired, 7 = Most Impaired)

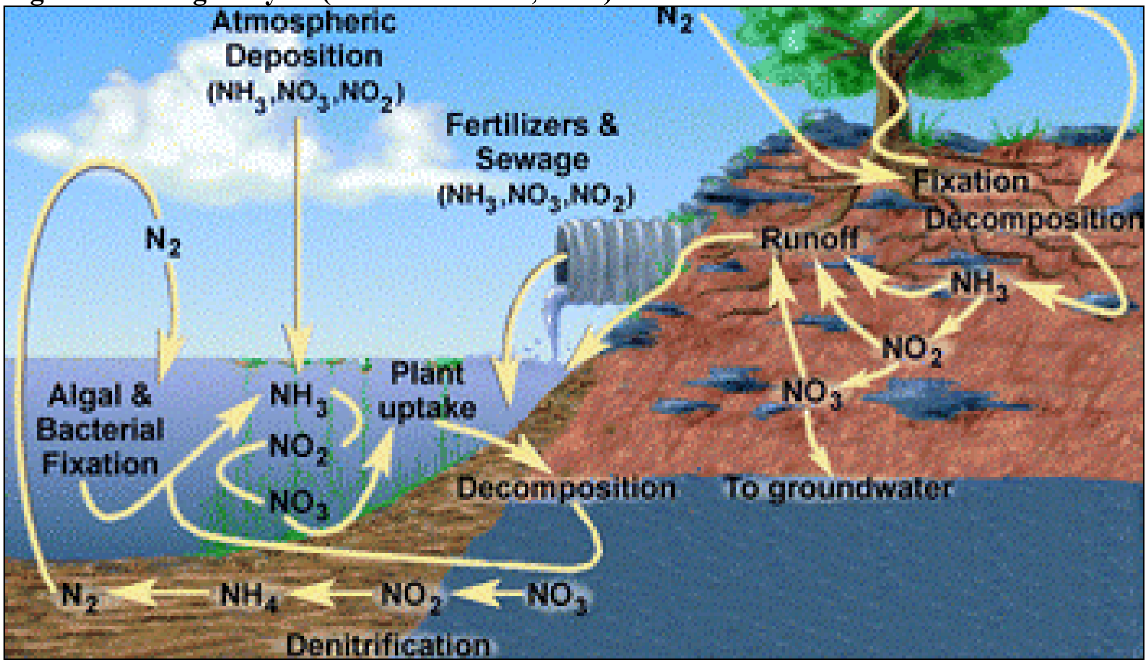
Site #	Average Mg/L	Median Mg/L	% of Samples Exceeding "High"	*Priority Ranking
Site # 1	0.42	0.4	0%	**4**
Site # 2	0.49	0.4	8%	**5**
Site # 3	0.26	0.2	0%	**2**
Site # 4	0.22	0.15	0%	**1**
Site # 5	0.32	0.3	0%	**3**
Site # 6	1.43	0.9	25%	**7**
Site # 7	0.53	0.4	9%	**6**

The sources of TKN at Site 2 likely originate from the Town of Monrovia from either domestic wildlife, failing septic systems, or inadequate wastewater treatment at Monrovia Middle School or the municipal wastewater treatment plant. Monitoring conducted for this project was not of sufficient detail to distinguish between these potential sources.

The sources of TKN at Sites 6 and 7 are most likely tied to the eutrophic nature of Patton Lake. Addition observations of the below average concentrations (as compared to the IDEM's 1996 study) of TKN entering Patton Lake at Site 5 suggest that the cause of this eutrophication is likely the land uses immediately surrounding the lake. In eutrophic lakes, anoxia results in increased levels of nitrogen with increasing depth in the hypolimnion. When the hypolimnion of a eutrophic lake becomes anoxic (lacking any oxygen), bacterial nitrification of ammonia ceases and nitrogen in the form of ammonium ion ($NH4+$) concentrations increase (Wisconsin DNR, 2003).

Denitrification only occurs at low oxygen levels, and is typically restricted to sediments, although it also occurs in the deoxygenated hypolimnia of some lakes. In eutrophic lakes that are stratified, concentrations of N2 may decline in the epilimnion because of reduced solubility as temperatures rise and increase in the hypolimnion from denitrification of nitrate (NO3) to nitrite (NO2) to inorganic nitrogen (N2). Nitrite (NO2) rarely accumulates except in the metalimnion and hypolimnion of eutrophic lakes (see **Figure 6**). Concentrations of nitrite in lakes are usually very low unless organic pollution is high (Wisconsin DNR, 2003).

Figure 6: Nitrogen Cycle (Wisconsin DNR, 2003)



Organic Carbon

Organic contaminants can enter waterways during periods of storm water runoff from many sources including insecticides, herbicides, agricultural chemicals and natural organic substances. Domestic wastewaters from improperly operated wastewater treatment facilities or failing septic systems also contribute organic contaminants in various amounts.

Total Organic Carbon (TOC) measurements are indicative of the number of carbon-containing compounds in a waterbody. The larger the organic carbon content, the more oxygen is consumed. A high organic content means an increase in the growth of microorganisms that contribute to the depletion of oxygen supplies. Elevated concentration of TOC can create unfavorable conditions for aquatic life, such as the depletion of oxygen and the presence of toxic substances.

In eutrophic lakes, the loading of organic matter to the hypolimnion and sediments increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion of stratified lakes is reduced progressively during the period of summer stratification at the deepest portion of the lake where a lower volume of water is exposed to the intensive oxygen consuming processes of decomposition at the surface of the lake sediments.

Steep watersheds tend to have less organic content in their soils and therefore contribute lower TOC concentrations from storm water runoff. In the project watershed, the primarily steep, forested nature topography suggests that sources of TOC are more likely to originate from human activities than from naturally occurring sources.

Elevated TOC concentrations are a cause of pollution in the project watershed. In the absence of a specific surface water quality standard for TOC, monitoring results collected during this monitoring project were also compared to the summary statistics and classification metrics from the IDEM’s 1996 West Fork White River study. An evaluation of the 1996 study’s summary statistics indicated that the average concentration of TKN for samples collected in the West Fork White River watershed was 4.08 mg/L, while the median concentration of TKN was 3.8 mg/L. Concentrations of TKN exceeding 4.4 mg/L were considered to be significantly elevated, while concentrations of phosphorus exceeding 4.8 mg/L were considered to be “high”.

A comparison of project monitoring results to the mean and median values observed in 1996 reveals that three stream reaches, Site 1 (Sycamore Creek downstream of Hart Lake), Site 4 (Highland Creek), Site 6 (Lamb’s Creek downstream of Patton Lake) and Site 7 (Lower Lamb’s Creek), had monitoring results that exceeded the “high” classification metric from the IDEM’s 1996 study (see **Graph 6**).

As illustrated in **Table 7**, monitoring locations were prioritized according to the level of TOC impairment, which was judged by the percentage of execeedances of the “High” classification metric as compared to the IDEM’s 1996 study of the West Fork White River. For sites without exceedances of the high classification, rankings are based on which sites maintained the lowest average TOC results. Note: This ranking is independent of the results from other parameters.

Graph 6: Total Organic Carbon (T.O.C) Monitoring Results, 2002 - 2003

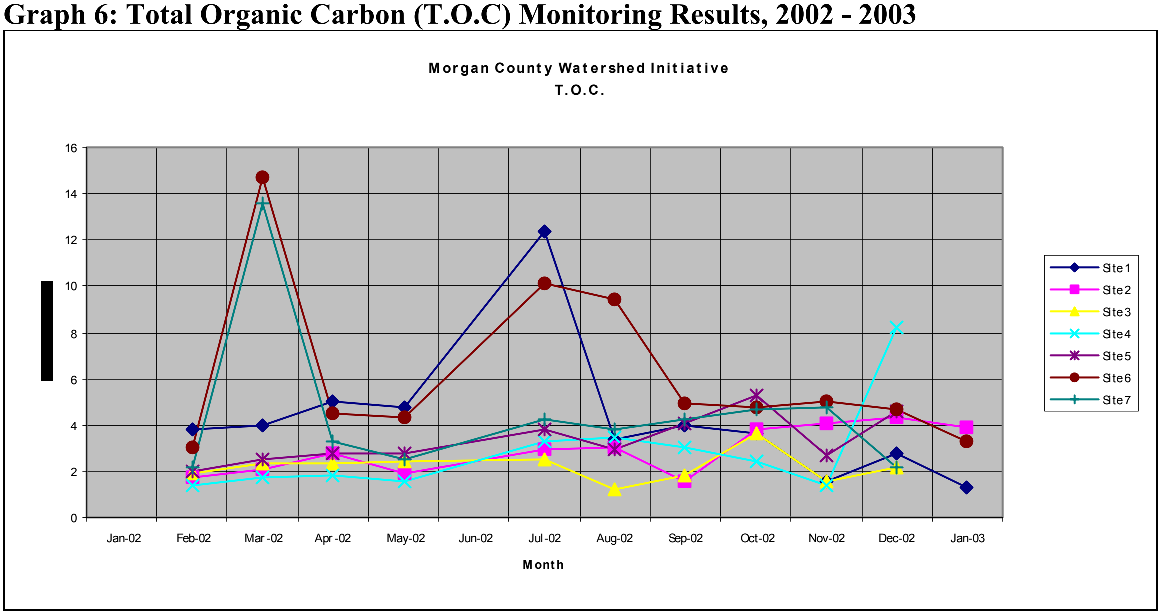


Table 7. TOC Monitoring Results (Average and Median) in Milligrams per Liter (Mg/L); Percentage of Samples Exceeding the IDEM’s 1996 “High” Classification Metric; Priority Ranking of Sites (1 = Least Impaired, 7 = Most Impaired)

Site #	Average Mg/L	Median Mg/L	% of Samples Exceeding “High”	*Priority Ranking
Site # 1	4.18	3.7	9%	**4**
Site # 2	2.64	2.45	0%	**2**
Site # 3	2.13	2.2	0%	**1**
Site # 4	2.68	1.8	10%	**5**
Site # 5	3.22	2.8	0%	**3**
Site # 6	5.98	4.75	36%	**7**
Site # 7	4.34	3.8	10%	**6**

Water Quality Summaries by Subwatershed

Sycamore Creek Subwatershed (Sites 1, 2 and 3)
The upper portions of the Sycamore Creek subwatershed, represented by Site 1 (downstream of Hart Lake) and Site 2 (downstream of Monrovia), is moderately impacted by various pollutants or display conditions that indicate the presence of water quality pollutants. Chemical monitoring within the subwatershed identified:

- elevated concentrations of *E.coli* bacteria at both Sites 1 and 2
- low concentrations of dissolved oxygen at both Sites 1 and 2
- periodic spikes of phosphorus at Site 1
- periodic spikes of nitrogen as both Sites 1 and 2
- elevated concentrations of organic carbon at Site 1
- elevated concentrations of specific conductance at Sites 1
- Bioassessment scores indicated the presence of poor quality macroinvertebrate communities at Site 1 and fair quality macroinvertebrate communities at Site 2.

The lower portion of Sycamore Creek, represented by Site 3 (Robb Hill Road), is slightly impacted by pollutants or pollution. Chemical monitoring within the subwatershed identified:

- elevated concentrations of E.coli, but only during wet weather
- above average dissolved oxygen concentrations throughout the year
- below average concentrations of phosphorus
- below average concentrations of nitrogen
- below average concentrations of organic carbon
- average concentrations of specific conductance
- Bioassessment scores indicated the presence of good quality macroinvertebrate communities at Site 3. This site qualifies as a "regional reference site," having habitat and an aquatic community among the best in Indiana..

Increase in the quality of the water quality monitoring results at Site 3 are indicative of the Sycamore Creek's natural ability to dilute, absorb and degrade water quality pollutants. Addressing the upstream sources of pollutants in the watershed should prove to further increase water and the quality of resident macroinvertebrate communities.

Highland Creek Subwatershed (Site 4)
The Highland Creek subwatershed, represented by Site 4 is moderately impacted by various pollutants or display conditions that indicate the presence of water quality pollutants. Chemical monitoring within the subwatershed identified:

- elevated concentrations of *E.coli* bacteria
- low concentrations of dissolved oxygen
- slightly elevated concentrations of phosphorus
- average concentrations of nitrogen
- periodic spikes in concentrations of organic carbon
- below average concentrations of specific conductance at Sites 1
- Bioassessment scores indicated the presence of poor quality macroinvertebrate communities.

A more thorough assessment of the Highland Creek subwatershed would be necessary to specifically diagnose the causes and sources of pollutants identified by this study. An evaluation of land uses within the subwatershed suggest that poor stream habitat (due to beaver dams), wildlife, livestock, and failing septic systems to be potential sources of pollution.

Lamb's Creek Subwatershed (Sites 5,6 and 7)
The upper portions of the Lamb's Creek subwatershed, represented by Site 5 (Lamb's Creek upstream of Patton Lake) is slightly impacted by various pollutants or display conditions that indicate the presence of water quality pollutants. Chemical monitoring within the subwatershed identified:

- elevated concentrations of *E.coli* bacteria
- low concentrations of dissolved oxygen during the warm weather months
- below average concentrations of phosphorus
- below average concentrations of nitrogen
- below average concentrations of organic carbon at Site 1
- below average concentrations of specific conductance at Sites 1
- Bioassessment scores indicated the presence of fair quality macroinvertebrate communities.

The lower portion of Lamb's Creek, represented by Sites 6 (Lamb's Creek downstream of Patton Lake) and Site 7 (Lower Lamb's Creek), is moderately impacted by pollutants or pollution. Chemical monitoring within the subwatershed identified:

- elevated concentrations of E.coli at both sites, particularly Site 7
- very low dissolved oxygen concentrations at Site 6
- high concentrations of phosphorus at Site 6
- high concentrations of nitrogen at both sites
- High concentrations of organic carbon at both sites
- average concentrations of specific conductance at both sites
- Bioassessment scores indicated the presence of fair quality macroinvertebrate communities at Site 6 and poor quality macroinvertebrate communities at Site 7.

The above average water quality observed at Site 5 upstream of Patton Lake juxtaposed with the generally poor water quality observations at Sites 6 and 7 suggest that the sources of pollutants and pollution present in the lower portions of the Lamb's creek watershed are due to land use activities immediately surrounding and downstream of Patton Lake. The presence of failing septic systems and additional pollutant contributions from storm water runoff containing wildlife and domestic animal wastes are the likely causes of the eutrophication that is negatively impacting Patton Lake.

Although many of the water quality problems observed at Site 7 are due upstream sources of pollution, primarily from Patton Lake, downstream land uses are also contributing to the water quality impairments observed at this site. Wildlife, livestock, failing septic systems and erosion are probable contributors to the pollutant loads documented at this site.

All data evaluated for this report are included in **Table 8: Morgan County Monitoring Project – Raw Data.**

Table 8: Morgan County Monitoring Project – Raw Data

Sample Date	Site ID	Waterbody Name	Location	Sample ID	Samp. Coll	D.O. (mg/L)	Temp. (C)	pH	Cond	Weather	TSS	Turbidity	T. Phos	T.O.C.	T.K.N.	E.coli
1/23/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	123021	sdh	8.5	10.6	7.6	*	4-18-1-2	4	1.69	0.03	3.5	**	160
2/27/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	227021	sdh	10.94	4.8	8.2	416	9-27-0-1	4	3.2	0.03	3.8	0.2	7
3/27/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	327021	sdh	11.98	5.4	8.5	412	2-27-0-2	13	9.2	0.04	4	0.4	110
4/30/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	430021	slm	9.15	15.2	8.4	360	3-27-1-4	12	13	0.4	5	1	110
5/30/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	530021	slm	6.1	23.5	8.6	354	1-27-0-4	4	2.7	0.03	4.8	0.4	23
7/31/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	731021	wma	5.38	25.6	8.2	407	1-27-0-5	4	1.4	0.03	12.4	0.5	69
8/28/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	828021	zdb	4.57	23	8	490	2-18-0-5	30	6.7	0.05	3.4	0.4	610
9/30/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	930021	zdb	6.2	19.8	8	430	3-27-1-4	6	2.3	0.03	4	0.4	110
10/30/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	1030021	wma	10.15	9.8	8.3	770	4-00-2-2	4	1.6	0.1	3.6	0.3	520
11/26/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	1126021	zdb	15.1	5	8.5	732	4-00-1-2	4	1.5	0.03	1.6	0.2	280
12/30/2002	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	1230021	zdb	11.28	8	8.2	595		9	10	0.06	2.8	0.6	440
1/31/2003	Site 1	Dry Fork of Sycamore Creek (d/s of Hart Lake)	CR 950 North	131031	zdb	20	2.1	10.8	708	4-27-0-2	4	1.2	0.04	1.3	0.2	190
1/23/2002	Site 2	Sycamore Creek	CR 950 North	123022	sdh	11.4	7.3	8	*	4-18-3-2	4	1.35	<0.03	1.1	**	610
2/27/2002	Site 2	Sycamore Creek	CR 950 North	227022	sdh	13.93	4.7	7.6	617	9-18-1-1	4	1.83	0.04	1.7	0.2	160
3/27/2002	Site 2	Sycamore Creek	CR 950 North	327022	sdh	11.76	6.1	8.4	571	2-27-0-2	11	6.5	0.05	2.1	0.5	340
4/30/2002	Site 2	Sycamore Creek	CR 950 North	430022	slm	9.22	14.6	8.6	593	2-27-1-4	10	4.6	0.05	2.8	0.8	190

5/30/2002	Site 2	Sycamore Creek	CR 950 North	530022	slm	9.8	19.4	8.7	672	1-27-0-4	4	4	0.07	1.9	0.2	730
7/31/2002	Site 2	Sycamore Creek	CR 950 North	731022	wma	6.88	23.6	8.4	761	1-27-0-5	13	5.7	0.12	2.9	1.5	2400
8/28/2002	Site 2	Sycamore Creek	CR 950 North	828022	zdb	7.95	21.5	8.2	776	2-18-0-5	8	4.1	0.09	1.5	0.3	690
9/30/2002	Site 2	Sycamore Creek	CR 950 North	930022	zdb	7.95	19	8.1	750	3-27-1-4	38	11	0.1	1.6	0.4	1000
10/30/2002	Site 2	Sycamore Creek	CR 950 North	1030022	wma	9.2	10.5	8.3	392	4-00-2-2	4	1.5	0.06	3.8	0.5	130
11/26/2002	Site 2	Sycamore Creek	CR 950 North	1126022	zdb	8.98	5	8.4	435	9-00-2-1	5	1.8	0.03	4.1	0.3	21
12/30/2002	Site 2	Sycamore Creek	CR 950 North	1230022	zdb	12.43	4.4	8.4	415	4-09-0-3	4	2.6	0.03	4.3	0.4	36
1/31/2003	Site 2	Sycamore Creek	CR 950 North	131032	zdb	17.41	1.7	6.9	445	4-27-0-1	5	1.3	0.03	3.9	0.3	1
1/23/2002	Site 3	Sycamore Creek	Robb Hill Road	123023	sdh	11.8	5.5	8.2	*	4-18-1-2	4	1.02	0.03	1.6	**	34
2/27/2002	Site 3	Sycamore Creek	Robb Hill Road	227023	sdh	13.59	2.5	8.5	429	9-18-1-1	4	1.3	0.03	1.9	0.1	6
3/27/2002	Site 3	Sycamore Creek	Robb Hill Road	327023	sdh	12.16	3.9	8.6	395	2-27-0-2	10	9	0.03	2.3	0.3	100
4/30/2002	Site 3	Sycamore Creek	Robb Hill Road	430023	slm	9.31	13.5	8.5	408	3-27-1-4	7	3.8	0.03	2.3	0.5	150
5/30/2002	Site 3	Sycamore Creek	Robb Hill Road	530023	slm	8.3	23.5	8.9	449	1-00-1-4	4	1.6	0.03	2.4	0.1	310
7/31/2002	Site 3	Sycamore Creek	Robb Hill Road	731023	wma	7.8	26.9	8.5	571	1-27-0-5	7	2.9	0.03	2.5	0.2	49
8/28/2002	Site 3	Sycamore Creek	Robb Hill Road	828023	zdb	7.7	24.5	8	541	3-18-1-5	5	2.5	0.03	1.2	0.2	42
9/30/2002	Site 3	Sycamore Creek	Robb Hill Road	930023	zdb	6.89	18.6	8	545	3-27-0-4	4	0.81	0.03	1.8	0.2	93
10/30/2002	Site 3	Sycamore Creek	Robb Hill Road	1030023	wma	7.4	9.3	8.3	511	4-00-2-2	4	2.7	0.03	3.6	0.2	2400

11/26/2002	Site3	Sycamore Creek	Robb Hill Road	1126023	zdb	10.6	2.9	8.4	585	4-09-2-3	4	1.1	0.03	1.6	0.2	21
12/30/2002	Site 3	Sycamore Creek	Robb Hill Road	1230023	zdb	12.38	3.4	8.5	526	4-09-0-3	4	2.4	0.03	2.2	0.6	200
1/31/2003	Site 3	Sycamore Creek	Robb Hill Road	131033	zdb	Frozen										
1/23/2002	Site 4	Highland Creek	SR 67	123024	sdh	12.5	4.7	8	*	4-18-1-2	7	6.9	0.04	1.2	**	490
2/27/2002	Site 4	Highland Creek	SR 67	227024	sdh	11.2	2.2	8.4	194	9-27-1-1	4	3.15	0.03	1.4	0.1	10
3/27/2002	Site 4	Highland Creek	SR 67	327024	sdh	11.5	4	8.3	180	2-27-0-2	15	9.2	0.03	1.7	0.2	44
4/30/2002	Site 4	Highland Creek	SR 39	430024d	slm	9.27	13.1	7.9	166	1-27-1-4	23	15	0.03	1.8	0.1	38
5/30/2002	Site 4	Highland Creek	SR 39	530024	slm	8.5	18.6	8.4	207	1-00-0-4	4	2.7	0.03	1.6	0.1	220
7/31/2002	Site 4	Highland Creek	SR 39	731024	wma	4.3	27.5	8	375	1-27-1-5	25	17	0.05	3.3	0.4	110
8/28/2002	Site 4	Highland Creek	SR 39	828024	zdb	2.34	23.4	7.7	398	3-18-1-5	24	20	0.09	3.5	0.6	150
9/30/2002	Site 4	Highland Creek	SR 39	930024	zdb	2.6	18.7	7.1	384	3-27-1-4	17	12	0.04	3	0.3	1300
10/30/2002	Site 4	Highland Creek	SR 39	1030024	wma	8.95	9.2	8.1	317	4-00-2-2	4	3	0.03	2.4	0.1	260
11/26/2002	Site 4	Highland Creek	SR 39	1126024	zdb	9.5	4.3	8.4	294	4-00-1-2	6	3.1	0.03	1.4	0.1	10
12/30/2002	Site 4	Highland Creek	SR 39	1230024	zdb	11.88	4.7	8.4	291	4-09-0-3	18	15	0.04	8.2	0.2	440
1/31/2003	Site 4	Highland Creek	SR 39	131034	zdb	Frozen										
1/23/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	123025	sdh	9.2	10.5	8.2	*	5-18-0-2	4	3.8	0.03	1.8	**	86
2/27/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	227025	sdh	14.62	1.4	7.9	382	9-00-1-1	5	3.16	0.03	2	0.2	13
3/27/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	327025	sdh	12.67	3.2	8.4	361	2-27-0-2	19	15	0.05	2.6	0.4	120
4/30/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	430025	slm	9.42	13	7.6	369	1-27-2-3	14	9	0.04	2.8	0.3	170
5/30/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	530025	slm	10.9	20.9	9.1	395	1-00-0-4	4	4	0.03	2.8	0.2	250

7/31/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	731025	wma	7.07	30.9	8.5	409	1-27-0-5	25	17	0.05	3.8	0.5	7
8/28/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	828025	zdb	4.41	26.1	8	439	3-18-1-5	17	11	0.05	2.9	0.3	54
9/30/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	930025	zdb	5.95	21.6	8.1	448	1-27-1-4	11	5.2	0.05	4.1	0.3	140
10/30/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	1030025	wma	10.6	8.4	8.1	438	4-00-2-2	8	14	0.06	5.3	0.3	1100
11/26/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	1126025	zdb	13.4	2.8	8.4	504	4-00-0-2	11	3.1	0.03	2.7	0.1	120
12/30/2002	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	1230025	zdb	12.27	4.5	8.4	430	4-27-1-3	32	19	0.12	4.6	0.6	2400
1/31/2003	Site 5	Lambs Creek (u/s Patton Lake)	Upper Patton Lake Road	131035	zdb	Frozen										
1/23/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	123026	sdh	11.1	5.2	7.8	*	4-18-1-2	5	4.1	0.03	3.2	**	1
2/27/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	227026	sdh	11.61	5.3	8.2	319	9-00-1-1	13	13.2	0.04	2.9	0.5	1
3/27/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	327026	sdh	11.3	3.3	8.4	301	2-27-0-2	35	36	0.09	14.7	0.9	160
4/30/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	430026	slm	6.92	11.83	8.1	252	1-27-2-3	64	58	0.14	4.5	0.8	870

5/30/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	530026	slm	1.4	11.6	8.6	307	3-00-0-4	138	11	0.09	4.3	1	25
7/31/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	731026	wma	0.1	18.5	7.5	367	1-27-0-5	38	52	0.74	10.1	7	18
8/28/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	828026	zdb	0.15	19.8	7.2	412	4-18-0-5	64	120	1.47	9.4	1.6	11
9/30/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	930026	zdb	2.12	19.4	7.8	306	2-27-1-4	29	23	0.1	4.9	1.2	24
10/30/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	1030026	wma	4.3	10.5	7.9	353	4-00-2-2	35	27	0.09	4.8	0.9	17
11/26/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	1126026	zdb	10.4	4.5	8.3	326	4-00-1-2	12	7.7	0.04	5	0.6	4
12/30/2002	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	1230026	zdb	2.65	6.3	8.5	406	4-27-1-3	8	12	0.06	4.7	0.7	12
1/31/2003	Site 6	Lambs Creek (d/s Patton Lake)	Lower Patton Lake Road	131036	zdb	6.25	4.4	10.8	438	4-27-0-2	6	3.7	0.03	3.3	0.5	1
1/23/2002	Site 7	Lambs Creek	SR 67	37496	sdh	10.2	8.2	8	*	4-18-1-2	6	5.1	0.03	2.2	**	72
2/27/2002	Site 7	Lambs Creek	SR 67	227027	sdh	13.11	2.5	8.2	268	9-18-2-1	7	6.72	0.03	2.2	0.2	32
3/27/2002	Site 7	Lambs Creek	SR 67	327027	sdh	11.82	4.2	8.8	255	1-27-1-1	42	26	0.06	13.6	0.6	140
4/30/2002	Site 7	Lambs Creek	SR 67	430027	slm	7.9	12.6	8.9	244	1-27-2-3	35	30	0.07	3.3	0.4	550
5/30/2002	Site 7	Lambs Creek	SR 67	530027	slm	9	21.3	8.6	297	3-00-1-4	4	2.7	0.03	2.5	0.2	160
7/31/2002	Site 7	Lambs Creek	SR 67	731027	wma	6.27	27.5	8.2	369	1-27-1-5	22	14	0.08	4.2	1.1	1200
8/28/2002	Site 7	Lambs Creek	SR 67	828027	zdb	6.05	24.9	8.2	461	3-18-0-5	13	11	0.06	3.8	1.2	1200
9/30/2002	Site 7	Lambs Creek	SR 67	930027	zdb	8.45	19.8	8.1	366	1-27-0-5	9	6.1	0.05	4.2	0.6	820
10/30/2002	Site 7	Lambs Creek	SR 67	1030027	wma	7.8	9	8.3	349	4-00-2-2	7	6.5	0.07	4.7	0.4	690
11/26/2002	Site 7	Lambs Creek	SR 67	1126027	zdb	18.1	4.1	8.4	341	4-00-1-2	10	6.1	0.04	4.8	0.4	220

12/30/2002	Site 7	Lambs Creek	SR 67	1230027	zdb	12.1	4.3	8.9	366	4-09-1-3	4	3.8	0.03	2.2	0.2	460
1/31/2003	Site 7	Lambs Creek	SR 67	131037	zdb	Frozen										